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TITLE: OBJECT-ORIENTED PROCESS DOSE MODELING FOR GLOVEBOX OPERATIONS

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Object-Oriented Process Dose Modeling for Glovebox Operations

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I. Background

The Plutonium Facility at Los Alamos National Laboratory supports several defense and nondefense-related missions for the country by performing fabrication, surveillance, and research and development for materials and components that contain plutonium. Most operations occur in rooms with one or more arrays of gloveboxes connected to each other via trolley gloveboxes. Each room may contain gloveboxes dedicated to several different operations or functions.

Minimizing the effective dose equivalent (EDE) is a growing concern as a result of steadily declining allowable dose limits being imposed and a growing general awareness of safety in the workplace. In general, we discriminate three components of a worker's total EDE: the primary EDE, the secondary EDE, and background EDE. The immediate sources to which a worker is exposed provide the primary EDE. The secondary EDE results from operations and sources in the same vicinity or room as the worker. The background EDE results from all other sources of radiation, such as natural sources and sources outside of the room. A particular background source of interest is the nuclear materials vault. The distinction between sources inside and outside of a particular room is arbitrary with the underlying assumption that building walls and floors provide significant shielding to justify including sources in other rooms in the background category. An associated paper[1] details the tool that we use to determine the primary and secondary EDEs for all processes of interest in a room containing gloveboxes.

II. Process Modeling

The goal of process dose modeling is to obtain relatively accurate estimates of the dose equivalent received during operations involving radioisotopes. A great deal of effort and time has been devoted in the radiological engineering community to extensively model the transport of ionizing radiation through complicated geometries using sophisticated tools such as MCNP[2] and the DANT[3] suite of codes. These tools provide reliable estimates of the fluxes (and doses) in a given geometry; however, a tremendous effort would be required to use these tools to estimate doses in a production operation where the source configuration changes often.

A vast assortment of process modeling tools has been developed for analyzing production operations in various industries. Los Alamos has developed the Process Modeling System (ProMoS) primarily for performing process analyses of nuclear operations. ProMoS is an object-oriented, discrete-event simulation package that has been used to analyze operations at Los Alamos[4] and proposed facilities such as the new fabrication facilities for the Complex-21 effort.[5] In the past, crude estimates of the process dose (the EDE received when a particular process occurred), room dose (the EDE received when a particular process occurred in a given room), and facility dose (the EDE received when a particular process occurred in the facility) were used to obtain an integrated EDE for a given process. With the effort described in Ref. 1 and modifications to the ProMoS package to utilize secondary dose information, the dose modeling can be used to enhance the process modeling efforts.

The power of ProMoS quickly becomes evident when we consider the subtleties of process modeling. Fundamentally, ProMoS views the world as the capability to move resources such as materials, tools, and people, through containers, such as locations (a room or facility), workcenters (such as a glovebox), and bulk containers. Furthermore, the notion of resources is extended to allow for constraints on the resources. Given a schedule of operations and the resource pools, a detailed time history of part movement can be constructed. Given also the primary and secondary EDE information discussed previously, worker dose can be accumulated during a time for both the dose received from the worker's processes as well as the dose from other operations that occur in the same room while the worker is present. One time, the worker may be performing process A in the presence of process B. Another time, the worker may be working on process A in the room alone. In the former case, dose is accumulated for the appropriate time for both processes, where in the latter case, dose is accumulated only for the worker's process. Given the stochastic nature of the process occurrences, ProMoS is able to model an otherwise intractable problem.

III. An Example

A sample problem of plutonium metal preparation operations is provided to demonstrate the utility of process dose modeling. Three processes, molten-salt extraction (MSE), electrorefining (ER), and multi-cycle direct oxide reduction (MCDOR) are performed in a given room, along with a control panel operation. Analysis of the room layout using the tool described in Ref. 1 yields the EDE received by each process from each process per kilogram of source material. Since the feed plutonium is contaminated with amercium-241 and exists in 3 major bulk forms (metals, oxides, and chlorides) throughout the processes, a total of 6 EDE matrices are required. Table I is the EDE matrix for plutonium metal.

Table I. EDE matrix for process dose calculations for plutonium metal.

	Dose Providers			
Dose Receivers	MSE	ER	MCDOR	Control Panel
MSE	888.88	888.88	888.88	0
ER				0
MCDOR				0
Control Panel				0

Complicating the effort is the time-based variation in bulk-matrix at each process and the variation in americium contamination and removal efficiency for each process. The bulk matrix effects have been previously examined,[6] and are used to generate the EDE matrix. Because of the strong effect, the simulation of material movements must also adequately address the distinct phases of nuclear materials coupled to the location and presence of operational personnel in an accurate time-based manner.

A simplified flowsheet for these operations is shown in figure 1. Of particular operational interest is the likelihood that product output from MSE and MC-DOR meet foundry specifications and do not require Electrorefining. Further note that the electrorefining operation is the largest contributor to the residue recovery operations and thus has a direct impact on the MC-DOR operational requirements.

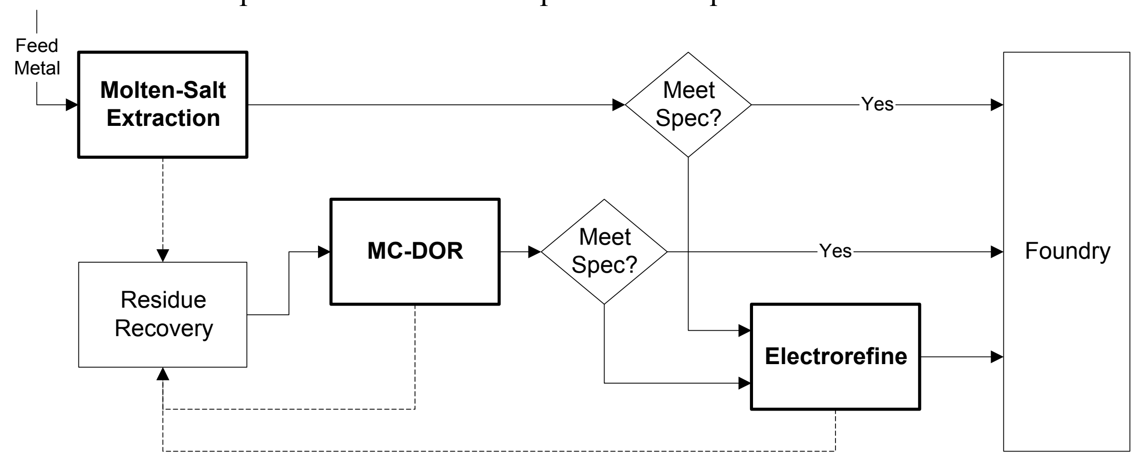

Figure 1. Flowsheet for Pyrochemcial Operations.

Using the ProMoS system, we estimate the Total EDE for a team of personnel as a function of the various process efficiencies. Process schedules, changes in team size and cross training, overall throughput, and americium-removal efficiencies as also evaluated in terms of overall EDE impact. This approach not only identifies the process-related trade-offs for EDE management, but allows for the evaluation of system-wide EDE reduction as a function of specific process improvements even though the system is constrained, feedback-controlled, and non-linear.

IV. References

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